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## **Shortest Path Routing Extensions for BGP Protocol draft-ietf-lsvr-bgp-spf-11**

### Abstract

Many Massively Scaled Data Centers (MSDCs) have converged on simplified layer 3 routing. Furthermore, requirements for operational simplicity have led many of these MSDCs to converge on BGP as their single routing protocol for both their fabric routing and their Data Center Interconnect (DCI) routing. This document describes a solution which leverages BGP Link-State distribution and the Shortest Path First (SPF) algorithm similar to Internal Gateway Protocols (IGPs) such as OSPF.

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## Table of Contents

<a href="#">1.</a>	<a href="#">Introduction</a>	<a href="#">3</a>
<a href="#">1.1.</a>	<a href="#">BGP Shortest Path First (SPF) Motivation</a>	<a href="#">4</a>
<a href="#">1.2.</a>	<a href="#">Requirements Language</a>	<a href="#">5</a>
<a href="#">2.</a>	<a href="#">BGP Peering Models</a>	<a href="#">5</a>
<a href="#">2.1.</a>	<a href="#">BGP Single-Hop Peering on Network Node Connections</a>	<a href="#">5</a>
<a href="#">2.2.</a>	<a href="#">BGP Peering Between Directly Connected Network Nodes</a>	<a href="#">5</a>
<a href="#">2.3.</a>	<a href="#">BGP Peering in Route-Reflector or Controller Topology</a>	<a href="#">6</a>
<a href="#">3.</a>	<a href="#">BGP-LS Shortest Path Routing (SPF) SAFI</a>	<a href="#">6</a>
<a href="#">4.</a>	<a href="#">Extensions to BGP-LS</a>	<a href="#">6</a>
<a href="#">4.1.</a>	<a href="#">Node NLRI Usage</a>	<a href="#">7</a>
<a href="#">4.1.1.</a>	<a href="#">Node NLRI Attribute SPF Capability TLV</a>	<a href="#">7</a>
<a href="#">4.1.2.</a>	<a href="#">BGP-LS Node NLRI Attribute SPF Status TLV</a>	<a href="#">8</a>
<a href="#">4.2.</a>	<a href="#">Link NLRI Usage</a>	<a href="#">8</a>
<a href="#">4.2.1.</a>	<a href="#">BGP-LS Link NLRI Attribute Prefix-Length TLVs</a>	<a href="#">9</a>
<a href="#">4.2.2.</a>	<a href="#">BGP-LS Link NLRI Attribute SPF Status TLV</a>	<a href="#">9</a>
<a href="#">4.3.</a>	<a href="#">Prefix NLRI Usage</a>	<a href="#">10</a>
<a href="#">4.3.1.</a>	<a href="#">BGP-LS Prefix NLRI Attribute SPF Status TLV</a>	<a href="#">10</a>
<a href="#">4.4.</a>	<a href="#">BGP-LS Attribute Sequence-Number TLV</a>	<a href="#">10</a>
<a href="#">5.</a>	<a href="#">Decision Process with SPF Algorithm</a>	<a href="#">11</a>
<a href="#">5.1.</a>	<a href="#">Phase-1 BGP NLRI Selection</a>	<a href="#">12</a>
<a href="#">5.2.</a>	<a href="#">Dual Stack Support</a>	<a href="#">13</a>
<a href="#">5.3.</a>	<a href="#">SPF Calculation based on BGP-LS NLRI</a>	<a href="#">13</a>
<a href="#">5.4.</a>	<a href="#">NEXT_HOP Manipulation</a>	<a href="#">16</a>
<a href="#">5.5.</a>	<a href="#">IPv4/IPv6 Unicast Address Family Interaction</a>	<a href="#">16</a>
<a href="#">5.6.</a>	<a href="#">NLRI Advertisement and Convergence</a>	<a href="#">17</a>
<a href="#">5.6.1.</a>	<a href="#">Link/Prefix Failure Convergence</a>	<a href="#">17</a>
<a href="#">5.6.2.</a>	<a href="#">Node Failure Convergence</a>	<a href="#">17</a>
<a href="#">5.7.</a>	<a href="#">Error Handling</a>	<a href="#">18</a>
<a href="#">6.</a>	<a href="#">IANA Considerations</a>	<a href="#">18</a>
<a href="#">7.</a>	<a href="#">Security Considerations</a>	<a href="#">18</a>
<a href="#">8.</a>	<a href="#">Management Considerations</a>	<a href="#">18</a>
<a href="#">8.1.</a>	<a href="#">Configuration</a>	<a href="#">18</a>
<a href="#">8.2.</a>	<a href="#">Operational Data</a>	<a href="#">19</a>
<a href="#">9.</a>	<a href="#">Implementation Status</a>	<a href="#">19</a>
<a href="#">10.</a>	<a href="#">Acknowledgements</a>	<a href="#">19</a>
<a href="#">11.</a>	<a href="#">Contributors</a>	<a href="#">20</a>



<a href="#">12.</a>	References . . . . .	<a href="#">20</a>
<a href="#">12.1.</a>	Normative References . . . . .	<a href="#">20</a>
<a href="#">12.2.</a>	Information References . . . . .	<a href="#">21</a>
	Authors' Addresses . . . . .	<a href="#">23</a>

## [1.](#) Introduction

Many Massively Scaled Data Centers (MSDCs) have converged on simplified layer 3 routing. Furthermore, requirements for operational simplicity have led many of these MSDCs to converge on BGP [[RFC4271](#)] as their single routing protocol for both their fabric routing and their Data Center Interconnect (DCI) routing. Requirements and procedures for using BGP are described in [[RFC7938](#)]. This document describes an alternative solution which leverages BGP-LS [[RFC7752](#)] and the Shortest Path First algorithm similar to Internal Gateway Protocols (IGPs) such as OSPF [[RFC2328](#)].

[[RFC4271](#)] defines the Decision Process that is used to select routes for subsequent advertisement by applying the policies in the local Policy Information Base (PIB) to the routes stored in its Adj-RIBs-In. The output of the Decision Process is the set of routes that are announced by a BGP speaker to its peers. These selected routes are stored by a BGP speaker in the speaker's Adj-RIBs-Out according to policy.

[[RFC7752](#)] describes a mechanism by which link-state and TE information can be collected from networks and shared with external components using BGP. This is achieved by defining NLRI advertised within the BGP-LS/BGP-LS-SPF AFI/SAFI. The BGP-LS extensions defined in [[RFC7752](#)] makes use of the Decision Process defined in [[RFC4271](#)].

This document augments [[RFC7752](#)] by replacing its use of the existing Decision Process. Rather than reusing the BGP-LS SAFI, the BGP-LS-SPF SAFI is introduced to insure backward compatibility. The Phase 1 and 2 decision functions of the Decision Process are replaced with the Shortest Path First (SPF) algorithm also known as the Dijkstra algorithm. The Phase 3 decision function is also simplified since it is no longer dependent on the previous phases. This solution avails the benefits of both BGP and SPF-based IGPs. These include TCP based flow-control, no periodic link-state refresh, and completely incremental NLRI advertisement. These advantages can reduce the overhead in MSDCs where there is a high degree of Equal Cost Multi-Path (ECMPs) and the topology is very stable. Additionally, using an SPF-based computation can support fast convergence and the computation of Loop-Free Alternatives (LFAs) [[RFC5286](#)] in the event of link failures. Furthermore, a BGP based solution lends itself to multiple peering models including those incorporating route-reflectors [[RFC4456](#)] or controllers.



Support for Multiple Topology Routing (MTR) as described in [\[RFC4915\]](#) is an area for further study dependent on deployment requirements.

### **[1.1.](#) BGP Shortest Path First (SPF) Motivation**

Given that [\[RFC7938\]](#) already describes how BGP could be used as the sole routing protocol in an MSDC, one might question the motivation for defining an alternate BGP deployment model when a mature solution exists. For both alternatives, BGP offers the operational benefits of a single routing protocol. However, BGP SPF offers some unique advantages above and beyond standard BGP distance-vector routing.

A primary advantage is that all BGP speakers in the BGP SPF routing domain will have a complete view of the topology. This will allow support for ECMP, IP fast-reroute (e.g., Loop-Free Alternatives), Shared Risk Link Groups (SRLGs), and other routing enhancements without advertisement of additional BGP paths or other extensions. In short, the advantages of an IGP such as OSPF [\[RFC2328\]](#) are available in BGP.

With the simplified BGP decision process as defined in [Section 5.1](#), NLRI changes can be disseminated throughout the BGP routing domain much more rapidly (equivalent to IGPs with the proper implementation).

Another primary advantage is a potential reduction in NLRI advertisement. With standard BGP distance-vector routing, a single link failure may impact 100s or 1000s prefixes and result in the withdrawal or re-advertisement of the attendant NLRI. With BGP SPF, only the BGP speakers corresponding to the link NLRI need withdraw the corresponding BGP-LS Link NLRI. This advantage will contribute to both faster convergence and better scaling.

With controller and route-reflector peering models, BGP SPF advertisement and distributed computation require a minimal number of sessions and copies of the NLRI since only the latest version of the NLRI from the originator is required. Given that verification of the adjacencies is done outside of BGP (see [Section 2](#)), each BGP speaker will only need as many sessions and copies of the NLRI as required for redundancy (e.g., one for the SPF computation and another for backup). Functions such as Optimized Route Reflection (ORR) are supported without extension by virtue of the primary advantages. Additionally, a controller could inject topology that is learned outside the BGP routing domain.

Given that controllers are already consuming BGP-LS NLRI [\[RFC7752\]](#), reusing for the BGP-LS SPF leverages the existing controller implementations.



Another potential advantage of BGP SPF is that both IPv6 and IPv4 can be supported in the same address family using the same topology. Although not described in this version of the document, multi-topology extensions can be used to support separate IPv4, IPv6, unicast, and multicast topologies while sharing the same NLRI.

Finally, the BGP SPF topology can be used as an underlay for other BGP address families (using the existing model) and realize all the above advantages. A simplified peering model using IPv6 link-local addresses as next-hops can be deployed similar to [\[RFC5549\]](#).

## **1.2. Requirements Language**

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [BCP 14](#) [\[RFC2119\]](#) [\[RFC8174\]](#) when, and only when, they appear in all capitals, as shown here.

## **2. BGP Peering Models**

Depending on the requirements, scaling, and capabilities of the BGP speakers, various peering models are supported. The only requirement is that all BGP speakers in the BGP SPF routing domain receive link-state NLRI on a timely basis, run an SPF calculation, and update their data plane appropriately. The content of the Link NLRI is described in [Section 4.2](#).

### **2.1. BGP Single-Hop Peering on Network Node Connections**

The simplest peering model is the one described in [section 5.2.1 of \[RFC7938\]](#). In this model, EBGP single-hop sessions are established over direct point-to-point links interconnecting the SPF domain nodes. For the purposes of BGP SPF, Link NLRI is only advertised if a single-hop BGP session has been established and the Link-State/SPF address family capability has been exchanged [\[RFC4790\]](#) on the corresponding session. If the session goes down, the corresponding Link NLRI will be withdrawn. Topologically, this would be equivalent to the peering model in [\[RFC7938\]](#) where there is a BGP session on every link in the data center switch fabric.

### **2.2. BGP Peering Between Directly Connected Network Nodes**

In this model, BGP speakers peer with all directly connected network nodes but the sessions may be multi-hop and the direct connection discovery and liveness detection for those connections are independent of the BGP protocol. How this is accomplished is outside the scope of this document. Consequently, there will be a single





session even if there are multiple direct connections between BGP speakers. For the purposes of BGP SPF, Link NLRI is advertised as long as a BGP session has been established, the Link-State/SPF address family capability has been exchanged [[RFC4790](#)] and the corresponding link is considered up and considered operational. This is much like the previous peering model only peering is on a single loopback address and the switch fabric links can be unnumbered. However, there will be the same number of sessions as with the previous peering model unless there are parallel links between switches in the fabric.

### **2.3. BGP Peering in Route-Reflector or Controller Topology**

In this model, BGP speakers peer solely with one or more Route Reflectors [[RFC4456](#)] or controllers. As in the previous model, direct connection discovery and liveness detection for those connections are done outside the BGP protocol. More specifically, the Liveness detection is done using BFD protocol described in [[RFC5880](#)]. For the purposes of BGP SPF, Link NLRI is advertised as long as the corresponding link is up and considered operational.

This peering model, known as sparse peering, allows for many fewer BGP sessions and, consequently, instances of the same NLRI received from multiple peers. It is discussed in greater detail in [[I-D.ietf-lsvr-applicability](#)].

## **3. BGP-LS Shortest Path Routing (SPF) SAFI**

In order to replace the Phase 1 and 2 decision functions of the existing Decision Process with an SPF-based Decision Process and streamline the Phase 3 decision functions in a backward compatible manner, this draft introduces the BGP-LS-SFP SAFI for BGP-LS SPF operation. The BGP-LS-SPF (AFI 16388 / SAFI TBD1) [[RFC4790](#)] is allocated by IANA as specified in the [Section 6](#). A BGP speaker using the BGP-LS SPF extensions described herein MUST exchange the AFI/SAFI using Multiprotocol Extensions Capability Code [[RFC4760](#)] with other BGP speakers in the SPF routing domain.

## **4. Extensions to BGP-LS**

[RFC7752] describes a mechanism by which link-state and TE information can be collected from networks and shared with external components using BGP protocol. It describes both the definition of BGP-LS NLRI that describes links, nodes, and prefixes comprising IGP link-state information and the definition of a BGP path attribute (BGP-LS attribute) that carries link, node, and prefix properties and attributes, such as the link and prefix metric or auxiliary Router-IDs of nodes, etc.



Note that usage of Strict Shortest Path First (SPF) algorithm is defined in the IGP algorithm registry but usage is restricted to [[I-D.ietf-idr-bgpls-segment-routing-epe](#)]. Hence, its usage for BGP-LS SPF is out of scope.



The link IGP metric attribute TLV (TLV 1095) as well as any others required for non-SPF purposes SHOULD be advertised. The metric value in this TLV is variable length dependent on specific protocol usage (refer to [section 3.3.2.4 in \[RFC7752\]](#)). For simplicity, the BGP-LS



SPF metric length will be 4 octets. Algorithms such as setting the metric inversely to the link speed as done in the OSPF MIB [[RFC4750](#)] MAY be supported. However, this is beyond the scope of this document.

#### [4.2.1.](#) BGP-LS Link NLRI Attribute Prefix-Length TLVs

Two BGP-LS Attribute TLVs to BGP-LS Link NLRI are defined to advertise the prefix length associated with the IPv4 and IPv6 link prefixes. The prefix length is used for the optional installation of prefixes corresponding to Link NLRI as defined in [Section 5.3](#).

```

      0                   1                   2                   3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|      TBD IPv4 or IPv6 Type      |      Length      |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| Prefix-Length |
+---+---+---+---+---+

```

Prefix-length - A one-octet length restricted to 1-32 for IPv4 Link NLRI endpoint prefixes and 1-128 for IPv6 Link NLRI endpoint prefixes.

#### [4.2.2.](#) BGP-LS Link NLRI Attribute SPF Status TLV

A BGP-LS Attribute TLV to BGP-LS Link NLRI is defined to indicate the status of the link with respect to the BGP SPF calculation. This will be used to expedite convergence for link failures as discussed in [Section 5.6.1](#). If the SPF Status TLV is not included with the Link NLRI, the link is considered up and available.

```

      0                   1                   2                   3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|   TBD Type   |      Length      |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
| SPF Status   |
+---+---+---+---+---+

```

BGP Status Values: 0 - Reserved

1 - Link Unreachable with respect to BGP SPF

2-254 - Undefined

255 - Reserved





### 4.3. Prefix NLRI Usage

Prefix NLRI is advertised with a local node descriptor as described above and the prefix and length used as the descriptors (TLV 265) as described in [\[RFC7752\]](#). The prefix metric attribute TLV (TLV 1155) as well as any others required for non-SPF purposes SHOULD be advertised. For loopback prefixes, the metric should be 0. For non-loopback prefixes, the setting of the metric is a local matter and beyond the scope of this document.

#### 4.3.1. BGP-LS Prefix NLRI Attribute SPF Status TLV

A BGP-LS Attribute TLV to BGP-LS Prefix NLRI is defined to indicate the status of the prefix with respect to the BGP SPF calculation. This will be used to expedite convergence for prefix unreachability as discussed in [Section 5.6.1](#). If the SPF Status TLV is not included with the Prefix NLRI, the prefix is considered reachable.

```

      0                   1                   2                   3
      0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|   TBD Type   |                                     Length       |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|  SPF Status  |
+---+---+---+---+---+

```

BGP Status Values: 0 - Reserved

1 - Prefix down with respect to SPF

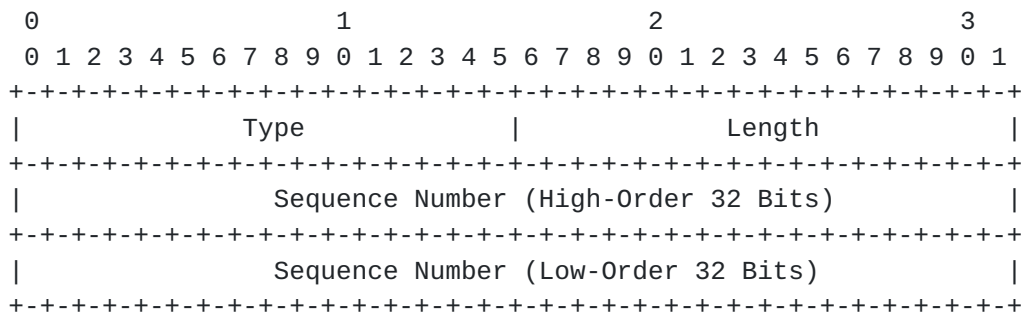
2-254 - Undefined

255 - Reserved

### 4.4. BGP-LS Attribute Sequence-Number TLV

A new BGP-LS Attribute TLV to BGP-LS NLRI types is defined to assure the most recent version of a given NLRI is used in the SPF computation. The TBD TLV type will be defined by IANA. The new BGP-LS Attribute TLV will contain an 8-octet sequence number. The usage of the Sequence Number TLV is described in [Section 5.1](#).





The 64-bit strictly increasing sequence number is incremented for every version of BGP-LS NLRI originated. BGP speakers implementing this specification MUST use available mechanisms to preserve the sequence number's strictly increasing property for the deployed life of the BGP speaker (including cold restarts). One mechanism for accomplishing this would be to use the high-order 32 bits of the sequence number as a wrap/boot count that is incremented anytime the BGP router loses its sequence number state or the low-order 32 bits wrap.

When incrementing the sequence number for each self-originated NLRI, the sequence number should be treated as an unsigned 64-bit value. If the lower-order 32-bit value wraps, the higher-order 32-bit value should be incremented and saved in non-volatile storage. If by some chance the BGP Speaker is deployed long enough that there is a possibility that the 64-bit sequence number may wrap or a BGP Speaker completely loses its sequence number state (e.g., the BGP speaker hardware is replaced or experiences a cold-start), the phase 1 decision function (see [Section 5.1](#)) rules will insure convergence, albeit, not immediately.

The Decision Process described in [[RFC4271](#)] takes place in three distinct phases. The Phase 1 decision function of the Decision Process is responsible for calculating the degree of preference for each route received from a BGP speaker's peer. The Phase 2 decision function is invoked on completion of the Phase 1 decision function and is responsible for choosing the best route out of all those available for each distinct destination, and for installing each chosen route into the Loc-RIB. The combination of the Phase 1 and 2 decision functions is characterized as a Path Vector algorithm.

The SPF based Decision process replaces the BGP best-path Decision process described in [RFC4271]. This process starts with selecting only those Node NLRI whose SPF capability TLV matches with the local



BGP speaker's SPF capability TLV value. Since Link-State NLRI always contains the local descriptor [[RFC7752](#)], it will only be originated by a single BGP speaker in the BGP routing domain. These selected Node NLRI and their Link/Prefix NLRI are used to build a directed graph during the SPF computation. The best paths for BGP prefixes are installed as a result of the SPF process.

When BGP-LS-SPF NLRI is received, all that is required is to determine whether it is the best-path by examining the Node-ID and sequence number as described in [Section 5.1](#). If the received best-path NLRI had changed, it will be advertised to other BGP-LS-SPF peers. If the attributes have changed (other than the sequence number), a BGP SPF calculation will be scheduled. However, a changed NLRI MAY be advertised to other peers almost immediately and propagation of changes can approach IGP convergence times. To accomplish this, the MinRouteAdvertisementIntervalTimer and MinASOriginationIntervalTimer [[RFC4271](#)] are not applicable to the BGP-LS-SPF SAFI. Rather, SPF calculations SHOULD be triggered and dampened consistent with the SPF back-off algorithm specified in [[RFC8405](#)].

The Phase 3 decision function of the Decision Process [[RFC4271](#)] is also simplified since under normal SPF operation, a BGP speaker would advertise the NLRI selected for the SPF to all BGP peers with the BGP-LS/BGP-LS-SPF AFI/SAFI. Application of policy would not be prevented however its usage to best-path process would be limited as the SPF relies solely on link metrics.

### **[5.1](#). Phase-1 BGP NLRI Selection**

The rules for NLRI selection are greatly simplified from [[RFC4271](#)].

1. If the NLRI is received from the BGP speaker originating the NLRI (as determined by the comparing BGP Router ID in the NLRI Node identifiers with the BGP speaker Router ID), then it is preferred over the same NLRI from non-originators. This rule will assure that stale NLRI is updated even if a BGP-LS router loses its sequence number state due to a cold-start.
2. If the Sequence-Number TLV is present in the BGP-LS Attribute, then the NLRI with the most recent, i.e., highest sequence number is selected. BGP-LS NLRI with a Sequence-Number TLV will be considered more recent than NLRI without a BGP-LS Attribute or a BGP-LS Attribute that doesn't include the Sequence-Number TLV.
3. The final tie-breaker is the NLRI from the BGP Speaker with the numerically largest BGP Router ID.



When a BGP speaker completely loses its sequence number state, i.e., due to a cold start, or in the unlikely possibility that that sequence number wraps, the BGP routing domain will still converge. This is due to the fact that BGP speakers adjacent to the router will always accept self-originated NLRI from the associated speaker as more recent (rule # 1). When BGP speaker reestablishes a connection with its peers, any existing session will be taken down and stale NLRI will be replaced by the new NLRI and stale NLRI will be discarded independent of whether or not BGP graceful restart is deployed, [RFC4724]. The adjacent BGP speaker will update their NLRI advertisements in turn until the BGP routing domain has converged.

The modified SPF Decision Process performs an SPF calculation rooted at the BGP speaker using the metrics from Link and Prefix NLRI Attribute TLVs [RFC7752]. As a result, any attributes that would influence the Decision process defined in [RFC4271] like ORIGIN, MULTI\_EXIT\_DISC, and LOCAL\_PREF attributes are ignored by the SPF algorithm. Furthermore, the NEXT\_HOP attribute value is preserved but otherwise ignored during the SPF or best-path.

## 5.2. Dual Stack Support

The SPF-based decision process operates on Node, Link, and Prefix NLRIs that support both IPv4 and IPv6 addresses. Whether to run a single SPF instance or multiple SPF instances for separate AFs is a matter of a local implementation. Normally, IPv4 next-hops are calculated for IPv4 prefixes and IPv6 next-hops are calculated for IPv6 prefixes. However, an interesting use-case is deployment of [RFC5549] where IPv6 next-hops are calculated for both IPv4 and IPv6 prefixes. As stated in [Section 1](#), support for Multiple Topology Routing (MTR) is an area for future study.

## 5.3. SPF Calculation based on BGP-LS NLRI

This section details the BGP-LS SPF local routing information base (RIB) calculation. The router will use BGP-LS Node, Link, and Prefix NLRI to populate the local RIB using the following algorithm. This calculation yields the set of intra-area routes associated with the BGP-LS domain. A router calculates the shortest-path tree using itself as the root. Variations and optimizations of the algorithm are valid as long as it yields the same set of routes. The algorithm below supports Equal Cost Multi-Path (ECMP) routes. Weighted Unequal Cost Multi-Path are out of scope. The organization of this section owes heavily to [section 16 of \[RFC2328\]](#).

The following abstract data structures are defined in order to specify the algorithm.





- o Local Route Information Base (RIB) - This is abstract contains reachability information (i.e., next hops) for all prefixes (both IPv4 and IPv6) as well as the Node NLRI reachability. Implementations may choose to implement this as separate RIBs for each address family and/or Node NLRI.
- o Link State NLRI Database (LSNDB) - Database of BGP-LS NLRI that facilitates access to all Node, Link, and Prefix NLRI as well as all the Link and Prefix NLRI corresponding to a given Node NLRI. Other optimization, such as, resolving bi-directional connectivity associations between Link NLRI are possible but of scope of this document.
- o Candidate List - This is a list of candidate Node NLRI with the lowest cost Node NLRI at the front of the list. It is typically implemented as a heap but other concrete data structures have also been used.

The algorithm is comprised of the steps below:

1. The current local RIB is invalidated. The local RIB is rebuilt during the course of the SPF computation. The existing routing entries are preserved for comparison to determine changes that need to be installed in the global RIB.
2. The computing router's Node NLRI is installed in the local RIB with a cost of 0 and as the sole entry in the candidate list.
3. The Node NLRI with the lowest cost is removed from the candidate list for processing. If the BGP-LS Node attribute includes an SPF Status TLV ([Section 4.1.2](#)) indicating the node is unreachable, the Node NLRI is ignored and the next lowest cost Node NLRI is selected from candidate list. The Node corresponding to this NLRI will be referred to as the Current Node. If the candidate list is empty, the SPF calculation has completed and the algorithm proceeds to step 6.
4. All the Prefix NLRI with the same Node Identifiers as the Current Node will be considered for installation. The cost for each prefix is the metric advertised in the Prefix NLRI added to the cost to reach the Current Node.
  - \* If the BGP-LS Prefix attribute includes an SPF Status TLV indicating the prefix is unreachable, the BGP-LS Prefix NLRI is considered unreachable and the next BGP-LS Prefix NLRI is examined.



- \* If the prefix is in the local RIB and the cost is greater than the Current route's metric, the Prefix NLRI does not contribute to the route and is ignored.
  - \* If the prefix is in the local RIB and the cost is less than the current route's metric, the Prefix is installed with the Current Node's next-hops replacing the local RIB route's next-hops and the metric being updated.
  - \* If the prefix is in the local RIB and the cost is same as the current route's metric, the Prefix is installed with the Current Node's next-hops being merged with local RIB route's next-hops.
5. All the Link NLRI with the same Node Identifiers as the Current Node will be considered for installation. Each link will be examined and will be referred to in the following text as the Current Link. The cost of the Current Link is the advertised metric in the Link NLRI added to the cost to reach the Current Node.
- \* Optionally, the prefix(es) associated with the Current Link are installed into the local RIB using the same rules as were used for Prefix NLRI in the previous steps.
  - \* If the current Node NLRI attributes includes the SPF status TLV ([Section 4.1.2](#)) and the status indicates that the Node doesn't support transit, the next link for the current node is processed.
  - \* The Current Link's endpoint Node NLRI is accessed (i.e., the Node NLRI with the same Node identifiers as the Link endpoint). If it exists, it will be referred to as the Endpoint Node NLRI and the algorithm will proceed as follows:
    - + If the BGP-LS Link NLRI attribute includes an SPF Status TLV indicating the link is down, the BGP-LS Link NLRI is considered down and the next BGP-LS Link NLRI is examined.
    - + All the Link NLRI corresponding the Endpoint Node NLRI will be searched for a back-link NLRI pointing to the current node. Both the Node identifiers and the Link endpoint identifiers in the Endpoint Node's Link NLRI must match for a match. If there is no corresponding Link NLRI corresponding to the Endpoint Node NLRI, the Endpoint Node NLRI fails the bi-directional connectivity test and is not processed further.



- + If the Endpoint Node NLRI is not on the candidate list, it is inserted based on the link cost and BGP Identifier (the latter being used as a tie-breaker).
  - + If the Endpoint Node NLRI is already on the candidate list with a lower cost, it need not be inserted again.
  - + If the Endpoint Node NLRI is already on the candidate list with a higher cost, it must be removed and reinserted with a lower cost.
- \* Return to step 3 to process the next lowest cost Node NLRI on the candidate list.
6. The local RIB is examined and changes (adds, deletes, modifications) are installed into the global RIB.

#### **5.4. NEXT\_HOP Manipulation**

A BGP speaker that supports SPF extensions MAY interact with peers that don't support SPF extensions. If the BGP-LS address family is advertised to a peer not supporting the SPF extensions described herein, then the BGP speaker MUST conform to the NEXT\_HOP rules specified in [[RFC4271](#)] when announcing the Link-State address family routes to those peers.

All BGP peers that support SPF extensions would locally compute the Loc-RIB next-hops as a result of the SPF process. Consequently, the NEXT\_HOP attribute is always ignored on receipt. However, BGP speakers SHOULD set the NEXT\_HOP address according to the NEXT\_HOP attribute rules specified in [[RFC4271](#)].

#### **5.5. IPv4/IPv6 Unicast Address Family Interaction**

While the BGP-LS SPF address family and the IPv4/IPv6 unicast address families install routes into the same device routing tables, they will operate independently much the same as OSPF and IS-IS would operate today (i.e., "Ships-in-the-Night" mode). There will be no implicit route redistribution between the BGP address families. However, implementation specific redistribution mechanisms SHOULD be made available with the restriction that redistribution of BGP-LS SPF routes into the IPv4 address family applies only to IPv4 routes and redistribution of BGP-LS SPF route into the IPv6 address family applies only to IPv6 routes.

Given the fact that SPF algorithms are based on the assumption that all routers in the routing domain calculate the precisely the same SPF tree and install the same set of routes, it is RECOMMENDED that



BGP-LS SPF IPv4/IPv6 routes be given priority by default when installed into their respective RIBs. In common implementations the prioritization is governed by route preference or administrative distance with lower being more preferred.

## **5.6. NLRI Advertisement and Convergence**

### **5.6.1. Link/Prefix Failure Convergence**

A local failure will prevent a link from being used in the SPF calculation due to the IGP bi-directional connectivity requirement. Consequently, local link failures should always be given priority over updates (e.g., withdrawing all routes learned on a session) in order to ensure the highest priority propagation and optimal convergence.

An IGP such as OSPF [[RFC2328](#)] will stop using the link as soon as the Router-LSA for one side of the link is received. With normal BGP advertisement, the link would continue to be used until the last copy of the BGP-LS Link NLRI is withdrawn. In order to avoid this delay, the originator of the Link NLRI will advertise a more recent version of the BGP-LS Link NLRI including the SPF Status TLV [Section 4.2.2](#) indicating the link is down with respect to BGP SPF. After some configurable period of time, e.g., 2-3 seconds, the BGP-LS Link NLRI can be withdrawn with no consequence. If the link becomes available in that period, the originator of the BGP-LS LINK NLRI will simply advertise a more recent version of the BGP-LS Link NLRI without the SPF Status TLV in the BGP-LS Link Attributes.

Similarly, when a prefix becomes unreachable, a more recent version of the BGP-LS Prefix NLRI will be advertised with the SPF Status TLV [Section 4.3.1](#) indicating the prefix is unreachable in the BGP-LS Prefix Attributes and the prefix will be considered unreachable with respect to BGP SPF. After some configurable period of time, e.g., 2-3 seconds, the BGP-LS Prefix NLRI can be withdrawn with no consequence. If the prefix becomes reachable in that period, the originator of the BGP-LS Prefix NLRI will simply advertise a more recent version of the BGP-LS Prefix NLRI without the SPF Status TLV in the BGP-LS Prefix Attributes.

### **5.6.2. Node Failure Convergence**

With BGP without graceful restart [[RFC4724](#)], all the NLRI advertised by node are implicitly withdrawn when a session failure is detected. If fast failure detection such as BFD is utilized, and the node is on the fastest converging path, the most recent versions of BGP-LS NLRI may be withdrawn while these versions are in-flight on longer paths. This will result the older version of the NLRI being used until the





new versions arrive and, potentially, unnecessary route flaps. Therefore, BGP-LS SPF NLRI SHOULD always be retained before being implicitly withdrawn for a brief configurable interval, e.g., 2-3 seconds. This will not delay convergence since the adjacent nodes will detect the link failure and advertise a more recent NLRI indicating the link is down with respect to BGP SPF [Section 5.6.1](#) and the BGP-SPF calculation will fail the bi-directional connectivity check.

### **[5.7.](#) Error Handling**

When a BGP speaker receives a BGP Update containing a malformed SPF Capability TLV in the Node NLRI BGP-LS Attribute [[RFC7752](#)], it MUST ignore the received TLV and the Node NLRI and not pass it to other BGP peers as specified in [[RFC7606](#)]. When discarding a Node NLRI with malformed TLV, a BGP speaker SHOULD log an error for further analysis.

## **[6.](#) IANA Considerations**

This document defines an AFI/SAFI for BGP-LS SPF operation and requests IANA to assign the BGP-LS/BGP-LS-SPF (AFI 16388 / SAFI TBD1) as described in [[RFC4760](#)].

This document also defines five attribute TLVs for BGP-LS NLRI. We request IANA to assign types for the SPF capability TLV, Sequence Number TLV, IPv4 Link Prefix-Length TLV, IPv6 Link Prefix-Length TLV, and SPF Status TLV from the "BGP-LS Node Descriptor, Link Descriptor, Prefix Descriptor, and Attribute TLVs" Registry.

## **[7.](#) Security Considerations**

This extension to BGP does not change the underlying security issues inherent in the existing [[RFC4271](#)], [[RFC4724](#)], and [[RFC7752](#)].

## **[8.](#) Management Considerations**

This section includes unique management considerations for the BGP-LS SPF address family.

### **[8.1.](#) Configuration**

In addition to configuration of the BGP-LS SPF address family, implementations SHOULD support the configuration of the INITIAL\_SPF\_DELAY, SHORT\_SPF\_DELAY, LONG\_SPF\_DELAY, TIME\_TO\_LEARN, and HOLDDOWN\_INTERVAL as documented in [[RFC8405](#)].



## **8.2. Operational Data**

In order to troubleshoot SPF issues, implementations SHOULD support an SPF log including entries for previous SPF computations. Each SPF log entry would include the BGP-LS NLRI SPF triggering the SPF, SPF scheduled time, SPF start time, SPF end time, and SPF type if different types of SPF are supported. Since the size of the log will be finite, implementations SHOULD also maintain counters for the total number of SPF computations of each type and the total number of SPF triggering events. Additionally, to troubleshoot SPF scheduling and back-off [[RFC8405](#)], the current SPF back-off state, remaining time-to-learn, remaining holddown, last trigger event time, last SPF time, and next SPF time should be available.

## **9. Implementation Status**

Note RFC Editor: Please remove this section and the associated references prior to publication.

This section records the status of known implementations of the protocol defined by this specification at the time of posting of this Internet-Draft, and is based on a proposal described in [[RFC7942](#)]. The description of implementations in this section is intended to assist the IETF in its decision processes in progressing drafts to RFCs. Please note that the listing of any individual implementation here does not imply endorsement by the IETF. Furthermore, no effort has been spent to verify the information presented here that was supplied by IETF contributors. This is not intended as, and must not be construed to be, a catalog of available implementations or their features. Readers are advised to note that other implementations may exist.

According to [RFC 7942](#), "this will allow reviewers and working groups to assign due consideration to documents that have the benefit of running code, which may serve as evidence of valuable experimentation and feedback that have made the implemented protocols more mature. It is up to the individual working groups to use this information as they see fit".

The BGP-LS SPF implementation status is documented in [[I-D.psarkar-lsvr-bgp-spf-impl](#)].

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